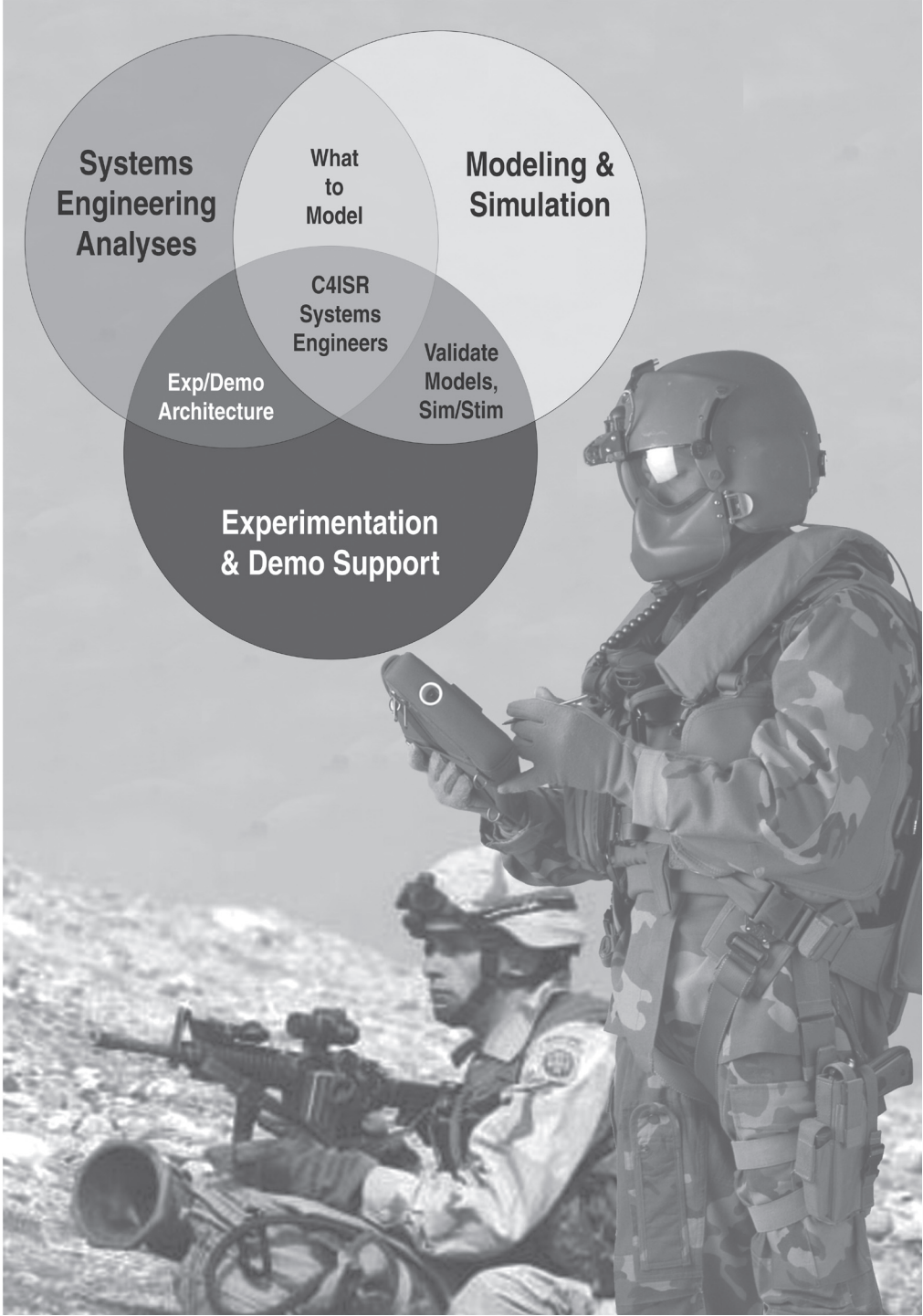


# C4ISR System of Systems Analysis



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# DEVELOPMENT AND ANALYSIS OF INTEGRATED C4ISR ARCHITECTURES

*Kristin Giammarco, Michael Carlomusto, and J. D. Lock*

The U.S. Army continues to struggle with creating doctrinally correct, robust, consistent, and all-inclusive operational, system, and technical views based on the Department of Defense Architecture Framework. Having detailed, integrated, and up-to-date architecture views is essential to answering questions involving alternative system designs and operating procedures, conducting gap, overlap, and connectivity analyses among programs of record, and providing traceable data upon which to base near- and far-term acquisition decisions as the armed services undergo Transformation. This paper presents an overview of the Communications-Electronics Research, Development, and Engineering Center Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) methodology for developing and utilizing integrated architecture products for the purposes of C4ISR System-of-Systems engineering analyses.

In support of Army leadership's efforts to make prudent and efficient acquisition decisions at the system-of-systems level, the Research, Development, and Engineering Command (RDECOM), Communications-Electronics Research, Development, and Engineering Center (CERDEC) has developed a structured and repeatable methodology for producing and analyzing integrated Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR), Department of Defense Architecture Framework (DoDAF) (DoDAF Architecture Framework Version 1, 2003) products. This integrated architecture process is a major component of the larger CERDEC Systems Analysis Processes and Tools (CSAP&T) methodology, which is a comprehensive systems engineering approach to the integration of architecture, Modeling and Simulation (M&S), and experimentation activities at CERDEC. Architecture products are used by CERDEC as vehicles for storing and relating essential information for analysis. They are designed to contain information needed for M&S, and be validated and updated based on virtual, live, and constructive experimentation.

The process described in this paper has evolved over the course of numerous studies done by the CERDEC Architecture and Systems Engineering Office (ASEO) for various Army customers, growing in fidelity and capability with each study. It is implemented at CERDEC using a tool called The Complete C4ISR Architectural Tool (TCAT), which was developed by CERDEC to meet specific M&S requirements for the architecture products and to improve traceability and reusability of data. The TCAT consists of a relational database with customized structured query language (SQL) scripts that present architecture information in the form of human-readable operational and system views and/or data files for use in other databases or spreadsheet programs, as well as M&S network simulation tools such as OPNET and QualNet. The TCAT database has been designed to be “tool agnostic,” meaning data can be moved into and out of TCAT as long as a common, specific data model is used. One of the specific data models used is an Extensible Markup Language (XML) implementation of the Core Architecture Data Model (CADM). The CADM XML tables are used to give a common structure to data in the Defense Architecture Repository System (DARS), a repository through which data may be shared with other architecture communities. Architectures in CERDEC’s C4ISR database are scoped to operational, system, and technical elements in Army Tactical and Operational echelons to a degree of fidelity (e.g. command post, platform/vehicle, staff section, dismounted soldier) that corresponds to source data availability and the scope of the architecture analysis being conducted. The process described in the following sections is currently implemented from the dismounted soldier through the Unit of Employment and can further scale to encompass all elements within the Global Information Grid (GIG) in a standardized form suitable for Joint C4ISR system-of-systems analyses. As such, the intent of this paper is to offer a high-level description of CERDEC’s integrated architecture methodology for peer evaluation of its applicability to Joint architectures and to solicit feedback for improvements as the requirement for system-of-systems analyses continues to grow in scope and fidelity.

## ARCHITECTURE DEFINED

In an integrated architecture framework, all of the operational views (OVs), system views (SVs), and technical views (TVs) are connected and consistent with one another. The relationships between the views are what define the actual architecture, and it is the common data elements among the views that provide the integration.

Table 1 summarizes the definitions (DoDAF, 2003) for each type of view. The all view (AV) contains high-level summary information about the architecture and includes references to the OVs, SVs, and TVs that make up the architecture. Because the architecture products are specifically developed for the purpose of conducting analyses, CERDEC also includes in the AV-1 the analysis questions being addressed, lessons learned, and tables showing OV/SV/TV traceability to the analysis questions and to the consumers/stakeholders, respectively.

**TABLE 1. PRODUCTION AND ANALYSES METHODOLOGY**

View	Definition
All View (AV)	Overarching aspects of an architecture that relate to all three of the views (e.g., scope, content).
Operational View (OV)	Description of the tasks and activities, operational elements, and information exchanges required to accomplish or support a military operation (e.g., information flows, information exchange requirements [IERs]).
Systems View (SV)	Description, including graphics, of systems, and interconnections providing for, or supporting, warfighting functions. Associates physical resources and their performance attributes to the operational view (e.g., platforms, systems, speed of service, maintainability, availability, priority, security classification).
Technical View (TV)	Minimal set of rules governing the arrangement, interaction, and interdependence of system parts or elements, whose purpose is to ensure that a conformant system satisfies a specified set of requirements (e.g., technical standards, implementation conventions, standards options, rules, criteria).

### BASIC TENETS OF C4ISR ARCHITECTURE ANALYSIS

In order to obtain consistent and meaningful analysis results, the CERDEC integrated architecture methodology and its implementation in the TCAT database are based on fundamental principles of C4ISR architecture development, as follows: *The process used to create the architecture is an integral part of the architecture itself.* A clearly defined and standardized process for architectural view development is employed for each study to ensure that a thoroughly consistent and integrated architecture is produced. Architecture products integrated and generated using TCAT are dependent upon certain practices that are observed throughout the architecture development process. These practices include obtaining relevant reference materials early on, utilizing appropriate subject matter expertise to extract required information, defining the relationships among key operational systems and technical data elements, and documenting assumptions regarding ambiguous or absent source data. Thus, the methodology, reference materials, and data element relationships and assumptions are delivered along with the architecture views for completeness and traceability.

*The basis of all architectures is the User's needs.* The input of the specific operational unit for which the architecture is being generated is required to ensure that the operational views reflect the doctrinal requirements and standing operating procedures (SOPs) of the unit. Also required are the specifics on how that unit would operationally employ each fielded system in the architecture. The modeled unit's input is a critical part of the methodology that ensures the validity of the architecture's operational, system, and

technical views, and therefore the validity and applicability of the resulting C4ISR traffic model and subsequent analysis results.

*Operational, system, and technical views must be consistent.* All products defining the same architecture are related and connected. An internally consistent architecture will have technical views that trace back to its system views and system views that trace back to its operational views. Without this interconnected traceability, a comprehensive identification of gaps between systems and operational functions/needs, and the impact of those gaps, would not be possible. A major part of accomplishing inherent consistency within an architecture is the early identification of source information needed to populate *all* of the relevant framework products. This source information is needed to understand and establish relationships among the source data elements that populate the views common to an architecture. Though certain source data *values* may not be immediately available, it is important to anticipate which data *fields* (i.e. data elements, such as producer, network service, security classification, etc.) will be subsequently required in analysis. Knowing which fields will be necessary in the architecture products at the outset of a study allows more time for collecting the field values and reserves placeholders for these values in each relevant architecture product. As the values are obtained, the architecture views are populated with relevant data. In this way, the architecture products are used as vehicles for storing and relating the data needed for analysis, and any change made in one view automatically propagates through all affected views.

## METHODOLOGY OVERVIEW

Before populating a single architecture product, the objectives of the analysis task and the questions to be addressed are determined. Once the purpose of the analysis is clearly established, AV products are drafted to document the scope of the architecture, and the data elements necessary to complete that analysis are identified. The architecture framework products that would contain those elements are then selected as appropriate vehicles for representing the data elements for analysis.

The AV-1 (Overview and Summary Information) is updated throughout the development of the architecture to summarize the scope, purpose, context, tools and file formats, findings/recommendations, and issues/lessons learned. The AV-1 serves two related purposes: 1) it serves as a planning guide during architecture development, and 2) upon completion of the architecture, the AV-1 is revised to document conclusions reached from the overall architectural development experience. The AV-2 (Integrated Dictionary) keeps track of terms and definitions used in the architecture. This integrated dictionary consists of textual information in the form of a glossary, including definitions of acronyms and architectural elements (e.g., activities, information flows, operational elements) used in the architecture. The AV-2 is an accompanying reference to the other products, and its value lies in the provision of unambiguous definitions among developers and users of the architecture.

Once the initial information for the AVs is identified, the necessary source data is assembled. The source data consists of the elements necessary to populate the

architecture framework products undergoing analysis. Since CERDEC uses the data in architecture products in M&S, there is a requirement for detail not commonly captured in existing DoDAF products. This detail is needed in the operational and systems exchange requirements in order to create an adequate model of C4ISR traffic within an operational unit. The foundation source data elements that are used to construct the architecture are as follows:

1. *Force Structure Elements* – Command centers, platforms/vehicles, staff sections, or individual soldiers that constitute the communicating operational entities within the organization. Also referred to as *Operational Elements* or *Operational Entities*.
2. *Operational Tasks* – Doctrinal activities performed by units and staffs in support of a mission, extracted from the Field Manual (FM 7-15) of the Army Universal Task List (AUTL) and the Chairman, Joint Chiefs of Staff Manual (CJCSM 3500.04C) Universal Joint Task List (UJTL). Operational Tasks are also sometimes referred to as *AUTLs/UJTLs*.
3. *ReMITs (Reports, Messages, ISR, Telemetry)* – This document is a catalog of approximately 570 specific types of C4ISR information that can be exchanged on the battlefield. It serves as a master pick-list of messages from the standard Variable Message Format (VMF), United States Message Text Formatting (USMTF), and Field Manual (FM 101-5-2) of U.S. Army Report and Message Formats, as well as Commander's Information Requirements (CIRs) and some Future Force messages not yet documented elsewhere. This master list was compiled with definitions by CERDEC and the TRADOC Analysis Center (TRAC), and is formatted for use in detailed analyses. This information is also referred to as *C4ISR Products* or *C4ISR Information Elements*.
4. *Format Parameters* – Each ReMIT has a specific perishability, cost of failure, precedence and security classification. ReMITs may occur in the *format* of data, imagery, voice, and/or vidstream. Each ReMIT format has certain *parameters* associated with it; such as data rate, frequency, size, duration, and speed of service. The values for the Format Parameters provide a quantitative value to each ReMIT.
5. *Systems* – For the purposes of present CERDEC analyses, a system is the sending or receiving end-user application or piece of communications equipment in the system architecture that is resourced to and used by a force structure element in the operational architecture. Systems are used to communicate information ReMITs from producers to consumers in support of operational requirements. Systems that have been represented in CERDEC studies include the Army Battle Command System (ABCS) applications and their application servers, Voice over Internet Protocol (VoIP) phones, generic computers/laptops, and collaboration/VTC equipment. The ABCS includes such systems as:
  - Maneuver Control System – Lite (MCS-L),



- All-Source Analysis System – Lite (ASAS-L),
- Global Command and Control System – Army (GCCS-A),
- Air and Missile Defense Workstation (AMDWS),
- Integrated Meteorological System (IMETS),
- Digital Topographical Support System – Lite (DTSS-L), and others.

The source data described above is used to populate architecture framework products that are either mission independent or mission specific. The distinction between the two types of products is summarized in Table 2.

The architecture framework products associated with the study are then exported from the data in the TCAT database. The DoDAF views currently able to be generated using TCAT include:

- OV-2 (Operational Node Connectivity Description),
- OV-3 (Operational Information Exchange Matrix),
- OV-6b (Operational State Transition Description),
- OV-6c (Operational Event-Trace Description), SV-4 (Systems Functionality Description),
- SV-5 (Operational Activity to Systems Function Traceability Matrix),

TABLE 2. FRAMEWORK PRODUCT DISTINCTIONS

Mission-Independent C4ISR Exchanges	Mission-Specific C4ISR Exchanges
Developed to conduct general traffic load analyses (e.g., average bandwidth through systems, into and out of operational elements)	Developed to conduct analysis on a specific mission thread (e.g., performance of the mission thread over a loaded network)
Regular interval traffic used to load the network	Each exchange is associated with a step in a mission thread
Unsequenced	Chronologically sequenced
A frequency field captures an average rate of occurrence for each unique exchange. There are no time stamps, and start/end times are arbitrary.	Each unique exchange occurs only once according to its time stamp. The first exchange(s) in the sequence starts when the mission thread is triggered.
100,000s to 1,000,000s of unique exchanges may be identified	100s to 1,000s of unique exchanges may be identified
Examples of traffic include common operational picture updates, ISR updates	Examples of traffic include a call for fire, a battle update brief



- SV-6 (Systems Data Exchange Matrix), and
- SV-10c (Systems Event-Trace Description).

Products that already exist for an architecture undergoing analysis are integrated into the database and augmented as needed, prior to generating the higher fidelity equivalent products utilized in M&S.

## TRAFFIC PROFILE DEVELOPMENT

An example of a specific type of analysis that CERDEC ASEO has conducted highlights the use of both mission independent and mission specific products. First, a unit-specific, mission independent product referred to as a *traffic profile* is developed. This product, populated based on the available source data, is used to estimate the offered load of background traffic on the C4ISR network being analyzed. Mission-specific products, referred to as *mission threads*, are then layered over the traffic profile to (among other uses described in Lindy, et al.) measure the performance of network services associated with the mission over the C4ISR network that is already loaded with background traffic.

This process for developing the traffic profile and mission threads for an architecture utilizes common reference data as well as the same set of relationships established among that reference data. Because the source data is common, both the traffic profile and the mission threads are developed to the same degree of fidelity for a given architecture.

The traffic profile consists of a subset of mission independent information exchanges between producer-consumer pairs that is directly traceable to the operational information exchange requirements and is required for modeling application-level user traffic. It contains information such as the producing and consuming operational elements, ReMIT, ReMIT format (data, imagery, voice or vidstream), ReMIT attributes (data rate, duration, size, frequency), and the following fields not captured in the architecture products:

1. *Network Services* – These are the delivery mechanisms used to transport ReMITs in the system architecture. Real-time services such as VoIP and Collaboration (e.g. Video Teleconferencing [VTC], whiteboarding, text chat, etc.) are identified in the system architecture for use in subsequent performance analyses, whereas non-real-time services such as Peer-to-Peer (between ABCS systems), E-mail, and Web/TACWeb are identified in order to understand the network load over which the real-time services must perform.
2. *Network* – This field identifies the physical networks that are used to transport the individual messages. Unclassified but Sensitive Internet Protocol Router Network (NIPRNET) and Secret Internet Protocol Router Network (SIPRNET) traffic are identified based on ReMITs and their security classifications. Joint

Worldwide Intelligence Communications System (JWICS) and Combat Service Support (CSS) traffic are identified based on ReMIT, and represent Intelligence and Logistics information respectively. Relationships of Systems and C4ISR information to specific Networks are used to analyze the load on each Network and explore information dissemination concepts.

To create a traffic profile, operational, systems, and technical subject matter experts (SMEs) first set up *source matrices*, which are used to establish relationships among the source data elements. A matrix is set up on a spreadsheet by listing data elements of one kind down the first column and data elements of another kind across the first row. The cells of the matrix are then populated to show the relationship between two data elements. The following relationships among data elements constitute the principle matrices used by CERDEC to construct integrated architecture products, including a traffic profile:

1. *Operational Tasks* performed during *Battle Phases*.
2. *Force Structure Elements* performing *Operational Tasks*.
3. *ReMITs* required to execute *Operational Tasks*.
4. *ReMITs* exchanged by *Force Structure Elements*.
5. *Format Parameters* associated with each *ReMIT*.
6. *Systems* resourced to *Force Structure Elements*.
7. *Operational Tasks* supported by *Systems*.
8. *ReMITs* exchanged by *Systems*.
9. *Network Services* available to *Systems*.
10. *Networks* available to *Systems*.

The matrices allow relationships among data elements to be assigned in a consolidated manner, and are the key to producing completely consistent architecture views. Note that some matrices relate system architecture data to operational architecture data, so that resulting OV and SVs are consistent with one another. (Technical View matrices are being integrated in 2005.) Furthermore, the matrices are set up to be modular, thus enabling architectural updates to be made in a matter of hours or days rather than weeks or months, allowing the effects of small changes to be studied before network configuration decisions are made.

The following is a brief description of each of the matrices listed above:

1. *Operational Tasks* performed during *Battle Phases*. This matrix captures the operational tasks (i.e., AUTLs and/or UJTLs) that are performed during each *phase of battle* (Objective Force: Unit of Employment Concept, 7 August, 2002): Entry, Shape, Decisive, and Transition (e.g., *Conduct Landing Zone Operations* during *Entry* phase).
2. *Force Structure Elements* performing *Operational Tasks*. This matrix captures each operational task performed by each force structure element according to the doctrinal requirements of the unit being analyzed (e.g., *3ID/UE-x/DIV HQ/DTAC CP1/ADA*<sup>1</sup> performs *Conduct Landing Zone Operations*).
3. *ReMITs* required to execute *Operational Tasks*. This matrix captures all C4ISR information (Reports, Messages, ISR, and Telemetry), known in short as *ReMITs*, needed for or generated by the completion of each operational task. Some tasks call for *ReMITs* being *generated* (produced) as output of the task, and some tasks call for *ReMITs* being *required* (consumed) as input to the task. This matrix just captures the doctrinal association of the *ReMITs* with each task, not who specifically is producing and consuming the information (e.g., an *INTSUM* (*Intelligence Summary*) is required to execute *Conduct Landing Zone Operations*).
4. *ReMITs* exchanged by *Force Structure Elements*. This matrix captures each *ReMIT* produced and consumed by each force structure element. This defines a general flow of information that is based on the unit's standing operating procedures (SOPs) (i.e., "business practices") that is independent of mission or scenario. This matrix provides the average C4ISR production and consumption at each element in the unit for use in subsequent bandwidth requirements analyses. This matrix is automatically cross-referenced with both the "*Force Structure Elements* performing *Operational Tasks*" and the "*ReMITs* required to execute *Operational Tasks*" doctrinal matrices to ensure the *ReMIT* flows defined in this SOP matrix support the operational tasks performed by each element in the unit. If any inconsistencies are found, the matrices are revisited and the necessary corrections are made before generating the final traffic profile that is used in analysis.
5. *Format Parameters* associated with each *ReMIT*. Each *ReMIT* may occur in one or more *formats*: data, imagery, voice, or vidstream. Every potential format of each *ReMIT* has a set of parameters assigned to it: *frequency* of occurrence (per hour) for each battle phase, *security classification*, *precedence*, *criticality*, and *perishability*. In addition, *size* (in kilobytes, before system and network overhead) is populated for the non-streaming formats of data and imagery, and *duration* (in seconds) and *data rate* (in kbps) are populated for the streaming formats of voice and vidstream. These format parameters quantify each *ReMIT* so that the C4ISR exchanges can later be simulated.
6. *Systems* resourced to *Force Structure Elements*. This relationship is extracted directly from the unit-specific System Architecture (SA) produced by the Program

Executive Office Command, Control and Communications Tactical/Office of the Chief Engineer Knowledge Engineering Information Laboratory (PEO C3T OCE KEIL). CERDEC ASE0 and OCE KEIL collaborate to load the TCAT database with data from the SA database so that updates to the KEIL system architecture are reflected in the CERDEC analyses. This collaboration allows for a consistent, timely, and configuration-controlled update to the traffic profile upon which the analysis is based and will eventually be expanded to allow a near real time update to both the data and the analysis results.

7. *Operational Tasks* supported by *Systems*. This set of mappings is used to help narrow the assignment of a system for an information exchange. It includes all the operational tasks that a particular system would be used to support. This information is provided by individual system subject matter experts.
8. *ReMITs* exchanged by *Systems*. This set of mappings is used to assign systems to an information exchange. It ensures that an information exchange is assigned to systems that are capable of exchanging it.
9. *Network Services* available to *Systems*. This is a set of mappings that are combined with programming logic to determine the network service used in the sending and the receiving of a ReMIT. Network Services include VoIP, Collaboration, Tactical Web (TACWEB), E-mail, Peer-to-Peer, and others. A different set of network services can be defined based on the needs of the particular analysis of the given system architecture.
10. *Networks* available to *Systems*. The assignment of networks is based on the system architecture source data and some programmed logic. Network examples are SIPR, NIPR, JWICS and CSS.

Once the basic matrices above are completed, SQL scripts are executed to generate the traffic profile and populate all the architecture products at once with the appropriate information required for each view. The traffic profile contains the user-generated C4ISR exchange requirements that need to occur no matter what the scenario is or where the unit is deployed. Once this baseline is constructed, customization can begin for various types of mission specific analyses.

## MISSION THREAD DEVELOPMENT

Architecture products containing mission-specific data can be layered over the traffic profile for various types of performance analyses. These views contain sequenced events among operational elements of the force structure and their systems.

The mission-specific products are built using the same source data as used in the traffic profile, and include additional information such as thread name, sequence

number, and a description for each task in the thread. For an in-depth description of the process used to generate mission-specific products (Lindy, et al.).

## PREPARING THE ARCHITECTURE FOR MODELING & SIMULATION

Upon final compilation of the architecture data for a given analysis, the data mined from the TCAT database (e.g., traffic profile, mission threads) are formatted for more specific M&S excursions to test the behavior of the network under various operational and technical circumstances.

The architecture products and the traffic profile alone do not capture the physical path of each exchange. They only capture the C4ISR exchanges that are associated with the end user (i.e., user traffic from producer to consumer). Internal network exchanges (i.e., network traffic among intermediary devices<sup>2</sup> needed to accomplish the end user exchanges must be added to account for overhead associated with dynamic network management traffic. Describing these internal exchanges in the architecture also helps to quantify subsequent analyses of information dissemination schemes.

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***The mission-specific products are built using the same source data as used in the traffic profile, and include additional information such as thread name, sequence number, and a description for each task in the thread.***

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The completed traffic profile serves as the basis for deriving the service flows and the application control profiles used for the bandwidth and performance analyses, respectively. In generating these derivative input files, first the server dispositions/locations for each service are incorporated into each data set. Secondly, the traffic is aggregated based on sender/receiver pair and service. Lastly, the data is translated into the formats required for driving the flow analysis tool and the OPNET simulation models.

At this point, the M&S phase of the analysis is entered. Briefly described, the data contained in the traffic model contributes to architectural analysis enabled by M&S analysis. Combined with models of communications assets and network services, analysis questions such as optimum server placement to minimize bandwidth requirements, performance of real-time applications (e.g., collaboration tools and VoIP) during busy times on the network, and suitability of a proposed Active Directory architecture are addressed in flow analysis and/or simulation runs, where parameters associated with network and service configurations can be varied. These analysis examples merely touch the surface of questions that can be and are being addressed using the CERDEC

CSAP&T process. Furthermore, new questions continuously arise as new issues are encountered both prior to unit deployment and in the field. The structured and repeatable process described above is an essential component to CERDEC's capability of adapting to changing architecture configurations, and its ability to quickly respond to analysis questions in time to be of help to the end user, the Warfighter.

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***The repeatability of the methodology and the experience gained in implementing it, as well as the availability of the large body of previous work are key factors in the success of enabling quick response analyses required by an Army at war.***

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For each analysis that employs the CSAP&T methodology, the body of work created in previous analyses is leveraged and built upon. Volumes of documentation are associated with each analysis activity, and include the data sets, reference materials/source data, assumptions, methodology description and study overview. Time-sensitive analysis results are distributed to stakeholders at regular intervals throughout the analysis as technical bulletins, which often spur new questions and a revisit to the analysis to conduct additional excursions and explore possible alternatives. The repeatability of the methodology and the experience gained in implementing it, as well as the availability of the large body of previous work are key factors in the success of enabling quick response analyses required by an Army at war.

## SUMMARY

The uniqueness of the methodology described in this article is that it provides a means to adapt to rapidly changing doctrine, systems, and parameters with efficiency and fidelity. Since much of the data is first created independently of mission, the same data may be reused, customized, and applied to various operational scenarios, missions, and conditions. All architecture data—regardless of its operational, system, or technical nature—is designated and stored in one common database. As such, consistency among the architecture products is guaranteed. Data common to more than one view is stored only once and referenced as many times as necessary. Furthermore, the work required to update the architecture is minimized. As the design evolves, the source data and the mappings in the matrices change. Whenever this happens, the modular nature of the matrices allows the affected portions of the architecture to be updated, and the SQL scripts are re-run so that all the views are updated simultaneously. Any changes to data

in one view propagate through to all affected views. This approach has reduced the turn-around time on updating highly detailed architecture products and corresponding analysis results, from months to days or even hours, allowing “what if” studies never before possible.

Since it is now possible to create an integrated architecture formatted for analysis in less time using the above methodology, and through efficiencies gained by collaboration with organizations such as the KEIL, the CERDEC has applied its resources towards conducting the C4ISR systems engineering analyses needed to make recommendations regarding the architecture to DA leadership, PEOs and PMs, as well as the end customer/user: the unit itself. Having developed a structured, repeatable approach to integrating and developing architectures as well as the foundational skill set to conduct and repeat various types of analyses in 2004, the ASEO continues to evolve its process to a level of efficiency such that analysis results can be obtained and used to support traceable recommendations prior to costly hardware development, software development, production and testing takes place.

The CERDEC CSAP&T methodology is embedded in doctrine, customizable to scenario, geography, systems and technology, able to represent Current Force, Modular Force, or Future Force task organizations and able to produce architectures with fidelity and resolution down to the dismounted soldier and up through Joint, Coalition and Strategic domains. Ultimately, it is our goal to have all OV, SVs and TVs (as well as relevant data not currently captured in any view) in a single automated systems engineering process designed for system-of-systems analysis, whose data elements are commonly defined across the Army community and beyond.





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## REFERENCE LIST

- DoDAF Architecture Framework Version 1.0. (2003, Jan). Office of the Assistant Secretary of Defense for Network Information and Integration, Washington D.C.
- Lindy, E., Dimarogonas, J., McConnell, J., & Farah-Stapleton, M. (2004). Representing Operational Architectures into a Modeling & Simulation Environment for Analyzing Communications Architectures, *Military Communications Conference (MILCOM) 2004 proceedings*.

## END NOTES

1. This is an example of a shorthand description that hierarchically represents a force structure element, and is read from right to left: The Air Defense Artillery (ADA) element (which could be a section, platoon, battery or staff liaison officer) in Division Tactical Command Post 1 (DTAC CP1) in Division Headquarters (DIV HQ) in Unit of Employment-x (UE-x) in the 3rd Infantry Division (3ID).
2. Intermediary devices include servers, routers, switches, and other network management devices comprising the actual network topology. These exchanges are accounted for separately in the traffic and simulation models.

## **ACRONYM KEY (IN ORDER OF APPEARANCE)**

- DoDAF – Department of Defense Architecture Framework
- CERDEC – Communications-Electronics Research, Development, and Engineering Center
- C4ISR – Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance
- SoS – System-of-Systems
- RDECOM – Research, Development, and Engineering Command
- CSAP&T – CERDEC Systems Analysis Processes and Tools
- M&S – Modeling and Simulation
- ASEO – Architecture and Systems Engineering Office
- TCAT – The Complete C4ISR Architectural Tool
- SQL – Structured Query Language
- XML – Extensible Markup Language
- CADM – Core Architecture Data Model
- DARS – Defense Architecture Repository System
- UE – Unit of Employment
- GIG – Global Information Grid
- OV – Operational View
- SV – Systems View
- TV – Technical View
- AV – All View
- SOP – Standing Operating Procedure
- FM – Field Manual
- CJCSM – Chairman, Joint Chiefs of Staff Manual
- AUTL – Army Universal Task List
- UJTL – Universal Joint Task List
- ReMIT – Reports, Messages, Intelligence/Surveillance/Reconnaissance, Telemetry
- VMF – Variable Message Format
- USMTF – United States Message Text Formatting
- CIR – Commander's Information Requirement

TRADOC – Training and Doctrine Command  
 TRAC – Training and Doctrine Command Analysis Center  
 ABCS – Army Battle Command System  
 VoIP – Voice over Internet Protocol  
 VTC – Video Teleconference  
 MCS-L – Maneuver Control System – Lite  
 ASAS-L – All-Source Analysis System – Lite  
 GCCS-A – Global Command and Control System – Army  
 AMDWS – Air and Missile Defense Workstation  
 IMETS – Integrated Meteorological System  
 DTSS-L – Digital Topographical Support System – Lite  
 TACWeb – Tactical Web  
 NIPRNET – Unclassified but Sensitive Internet Protocol Router Network  
 SIPRNET – Secret Internet Protocol Router Network  
 JWICS – Joint Worldwide Intelligence Communications System  
 CSS – Combat Service Support  
 SMEs – Subject Matter Experts  
 3ID – 3rd Infantry Division  
 UE-x – Unit of Employment-x  
 DIV HQ – Division Headquarters  
 DTAC CP1 – Division Tactical Command Post 1  
 ADA – Air Defense Artillery  
 SA – System Architecture  
 PEO – Program Executive Office  
 C3T – Command, Control, and Communications Tactical  
 OCE – Office of the Chief Engineer  
 KEIL – Knowledge Engineering Information Laboratory  
 DA – Department of the Army  
 PM – Program Manager